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BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Implication of a Violation of the 300 n.mi. Altitude Limit on Apollo 9 due to Late Launch
Case 310

DATE: February 14, 1969

FROM: R. Troester

ABSTRACT

A plan has been devised by MSC/Mission Planning and Analysis Division which provides a 3-hour launch window for the Apollo 9 flight but which will require maximum altitudes in the event of a late launch higher than the present 300 n.mi. earth orbit altitude limit specified in the Apollo Flight Mission Assignments document. Since the radiation hazard of the high orbits is minimal and will be monitored in real-time and since no degradation of communication or telemetry will result it is suggested that the 300 n.mi. altitude limit be waived for this mission.

(NASA-CR-103969) IMPLICATION OF A VIOLATION OF THE 300 N. MI. ALTITUDE LIMIT ON APOLLO 9 DUE TO LATE LAUNCH (Bellcomm, Inc.) 10 p

N79-71878

Unclas
00/13 11488

FF No. 602

(PAGES) (CODE)

CR 103969
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

[redacted]

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MEMORANDUM FOR FILE

INTRODUCTION

The Mission D Appendix of the Apollo Flight Mission Assignments document (AFMA) specifies a maximum altitude of 300 n.mi. for both CSM and LM during the Apollo 9 mission (Reference 1). The basis for this rule lies in a range constraint on the LM VHF-Development Flight Instrumentation (DFI) telemetry and the potential radiation hazard in the LM at high altitudes. In the nominal Apollo 9 mission the highest spacecraft altitude is never more than 270 n.mi. Nonetheless, the possibility does exist, if the spacecraft is launched at certain times within the three-hour launch window, that orbit apogee during a portion of the flight could rise to somewhat more than 500 n.mi. In order to understand how the high altitude orbit might affect the mission, the launch window design must first be examined in some detail.

PRESENT LAUNCH WINDOW DESIGN

For the Apollo 9 flight (originally the first manned Saturn V mission) it was desired to provide as long a launch window as possible. The principal constraints on the launch are the lighting conditions and tracking needed for the LM-active rendezvous on the fifth day of the mission. Originally, these two constraints limited the window to 15 minutes at most. However, Mission Planning and Analysis Division (MPAD) found that it would be possible to lengthen the window to about 3 hours (Reference 3) by a real-time retargeting of five of the six Service Propulsion System (SPS) and Descent Propulsion System (DPS) burns scheduled before the rendezvous (SPS-2, SPS-3, SPS-4, DPS-1, and SPS-5). For a late launch within the window the burns are targeted both to shift the line of nodes (Figure 1) and to adjust the orbit phasing (Figure 2), the object being to return the spacecraft to the same orbit plane and position in orbit it would have had in an on-time launch. The total nodal change capability of the SPS and DPS burns is the factor which limits the launch window*; the phasing capability is more than 360° and therefore not a problem.

*The present nodal change capability permits a launch window 3 hours 20 minutes long; however, it is not currently planned to utilize the last 20 minutes.

In order to simplify the crew/flight controller task the three-hour window has been divided into seven "panes" centered at half-hour intervals within which a single nodal shift targeting scheme is employed, as shown in Figure 1. The variation between panes has been restricted as well. Thus, all burns have a fixed ΔV and the three SPS burns before the phasing period (SPS-2, -3, and -4) occur at a fixed Ground Elapsed Time. Of the three major nodal shift burns, SPS-2 and SPS-3 are varied only in the out-of-plane component, which is pointed either north or south of the orbit track as required in order to shift the node east or west. The other nodal burn, DPS-1, is always targeted to return to the nominal 115x270 n.mi. orbit, no matter what may be the apogee resulting from the phasing burn, SPS-4.

In general this simplified plan will result in a nodal error. Analysis of the station coverage during the rendezvous (Reference 4) has shown that the maximum acceptable nodal error is 4-1/2 degrees east or west, i.e., about 15 minutes shift in launch time. The nodal error in the present MPAD plan is generally much less than 4-1/2 degrees except at the change-over points between panes where in some cases, as Figure 1 shows, it does attain this value.

The other component of the launch window design, phasing, is accomplished during the 11 to 13 orbits between the phasing burn, SPS-4, on the second day and the DPS burn on the third day. The nominal orbit after SPS-4 is 115x269 n.mi. For launch delays less than about 42 minutes apogee is lowered in order to allow the spacecraft to catch up to its nominal position. Beyond 42 minutes the required "apogee" drops below 115 n.mi., becoming perigee, and perigee switches from the northern hemisphere to the southern. Perigee in the southern hemisphere is undesirable since the DPS burn, which must take place over the United States, should occur at perigee in order to minimize the effects of any attitude excursions during the burn. Hence for launch delays between 43 and 96 minutes apogee is raised. In the higher orbit, the spacecraft's phase shifts backward relative to the nominal until the proper position is reached. In the second half of the window from 96 minutes to 180 minutes the same phasing technique is repeated. Therefore, as indicated by the sawtooth line in Figure 2, for launch delays between about 43 and 89 minutes and between 135 and 180 minutes SPS-4 will have to be retargeted to raise apogee above the 300 n.mi. AFMA limit. The actual apogees will be somewhat different from those shown in Figure 2 since SPS-4 will be adjusted in real-time to compensate for the dispersions in the previous burns, but the difference should not be great.

For planning purposes the phasing burn SPS-4 was limited to a fixed 300 fps total ΔV. This constrains the maximum apogee altitude to 445 n.mi. and consequently introduces a phasing error in those portions of the window where the required apogee (the dotted line) rises above the maximum. Since the 300 fps limit was self-imposed and since the extra ΔV required to fill the present "cracks" in the window is only 100 fps (this represents about 600 lb of propellant, 1/3 the SPS end-of-mission margin) MPAD believes there will be no problem in adjusting SPS-4 to accommodate the entire 3-hour launch window. Alternatively, the circularization burn, SPS-5, could be modified to circularize at an altitude other than 133 n.mi. (Reference 5). However, this phasing method is less desirable than is the increase in SPS-4 ΔV.

EFFECTS OF THE HIGH APOGEE ORBITS

Neither of the two potential high apogee problems, loss of telemetry and increased radiation, is a problem for the present Apollo 9 timeline. For orbits below 700 n.mi. the only significant radiation flux is received during passes through the South Atlantic Anomaly off the coast of Brazil. In the nominal mission the expected radiation skin dose to all the astronauts for the entire mission is .34 rad* two thirds of which is received during the 270 n.mi. apogee passes through the Anomaly from the second to the fourth day of the mission (Reference 6). This is not considered significant: the Planning Operational Dose (POD) for manned spaceflight, which is the upper limit for premission planning, is 250 rads skin dose while the real-time Maximum Operational Dose (MOD) is 400 rads (Reference 2). The depth dose, or dose to the blood-forming organs, is calculated to be about 1/2 the skin dose in the CM and less than 1/4 the skin dose in the LM. Since the POD for the depth dose is 25 rads and the MOD is 50 rads, the depth dose in the nominal orbit is also insignificant. With apogee at 500 n.mi. the dose is increased to about 1 rad for the Command Module Pilot (CMP) and to about 1-1/2 rad for the Commander (CDR) and LM Pilot (LMP). (The estimated error factor for the CM dose is about 2; the LM error factor is about 3.) The CDR/LMP dose is small even though the LM provides less than 1/10 the CM shielding because the astronauts do not man the LM during any passes through the Anomaly (Figure 3). But if the present timeline were extended or slipped by 12 hours, so that the LM were manned during the Anomaly passes, the skin dose in the LM could be as high as 30 rads. Assuming a twelve-hour slip in the timeline and a factor of 3 of error

*The Radiation Absorbed Dose (Rad) is a measure of the ionization power of radiation or particles. One rad is equivalent to 100 ergs/gram.

in the calculated radiation dose, the depth dose for the 500 n.mi. apogee orbit could approach the planning limit of 25 rads. The possibility of such a slippage is extremely remote, however, and no radiation hazard is envisaged for the nominal timeline in the high orbit. Additionally, radiation flux will be monitored real time and the commander and LM pilot can return to the CSM if the dosage rate becomes too high.

In the present timeline the potential communications problems are also minor even in a 500 n.mi. apogee orbit. The communications mode with the lowest circuit margins is the FM/FM LM Development Flight Instrumentation (DFI) telemetry link with Tananarive or the tracking ships. Maximum slant range for this mode is rated as 1200 n.mi. although a positive circuit margin exists at 1200 n.mi. and some data should be recoverable at greater distances. At 300 n.mi. altitude, the LM will exceed the 1200 n.mi. limit only for elevations less than 5° from the horizon, but at 500 n.mi. altitude it will exceed the limit at an elevation as high as 22°. Thus some loss of telemetry data is possible. However, due to the structure of the current timeline, the only activity which might be affected by the higher orbits is the Environmental Control System (ECS) activation over the tracking ship Mercury on the third mission day (Figure 3); other activities either are not planned near apogee or take place over higher-capability stations. MPAD has analyzed the station-coverage for the high apogee orbit and has found that although the time spent by the spacecraft outside the 1200 n.mi. range is greater than in the nominal mission, the "dwell time" within 1200 n.mi. is also greater, and no data should be lost (Reference 5). If for some reason the required five minutes of telemetry are not received in the pass over the Mercury, the data can be transmitted (assuming a small shift in the timeline) when the LM is powered up the following day over Carnarvon or perhaps on the day after that over the Canary Islands.

FCD POSITION

At the Apollo 9 Launch Mission Rules review held at KSC January 30, 1968, Flight Control Division (FCD) requested that KSC adjust the length of any hold which would delay lift-off beyond the nominal time so that launch will occur in the middle of a pane, where the nodal error is (roughly) zero. It was stated that while the restriction to launches at half hour centers is highly desirable, it is not mandatory, since the capability for a continuous launch window does exist. Restricting the window in this fashion to reduce the nodal error has the added advantage that the maximum orbit apogee can be reduced at the same time; for launches in the middle of the current panes (the open circles in Figure 2) the maximum apogee altitude is 440 n.mi. instead of 500 n.mi.

CONCLUSION

A plan has been devised by MPAD which allows a 3-hour launch window for the Apollo 9 flight but which may require maximum altitudes as high as 500 n.mi. during part of the mission. Since the radiation hazard of the high orbits is minimal and will be monitored in real-time and since no degradation of communication or telemetry will result, the 300 n.mi. altitude limit in the Apollo Flight Mission Assignments document should be waived for this mission.

Robert Troester

2013-RT-srb R. Troester

Attachments:
References
Figures

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2. "Space Environment Operations Plan AS-205/101" NASA/MSC FC043, October 1, 1968.

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4. Spurlin, H. O., "Effect of Nodal Errors on Apollo 9 Rendezvous" MSC/MPAD memo 68-FM64-368, December 20, 1968.

5. Telcons with Messrs. H. L. Conway and C. W. Pace MSC/ Mission Planning and Analysis Division, December 30, 1968; January 23 and 31, February 4, 1969.

6. Telcon with Mr. T. T. White, MSC/Space Physics Division January 23, 1969.

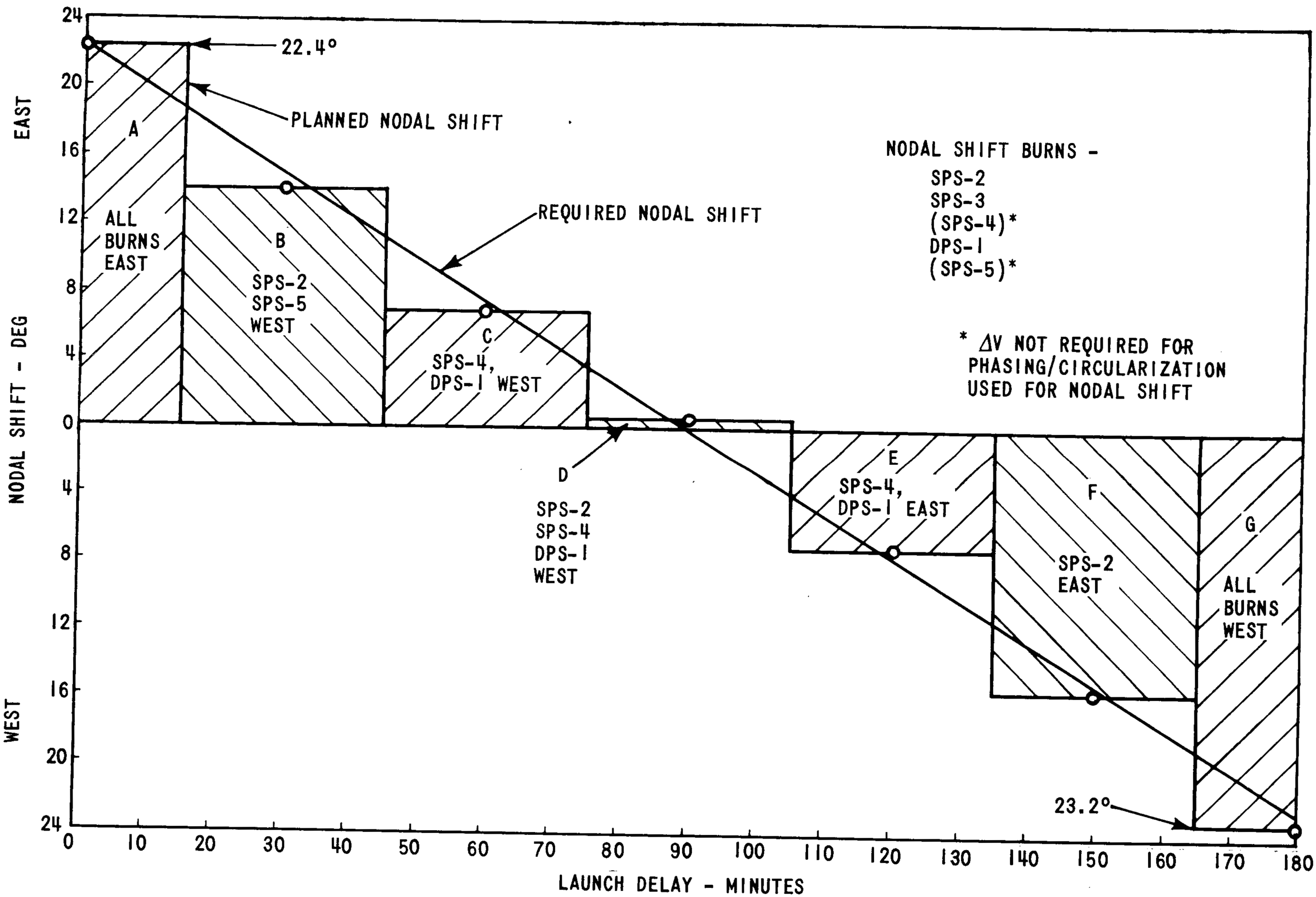


FIGURE 1 - APOLLO 9 REQUIRED AND PLANNED NODAL SHIFTS TO MAINTAIN PROPER LIGHTING/TRACKING FOR RENDEZVOUS AFTER A LATE LAUNCH

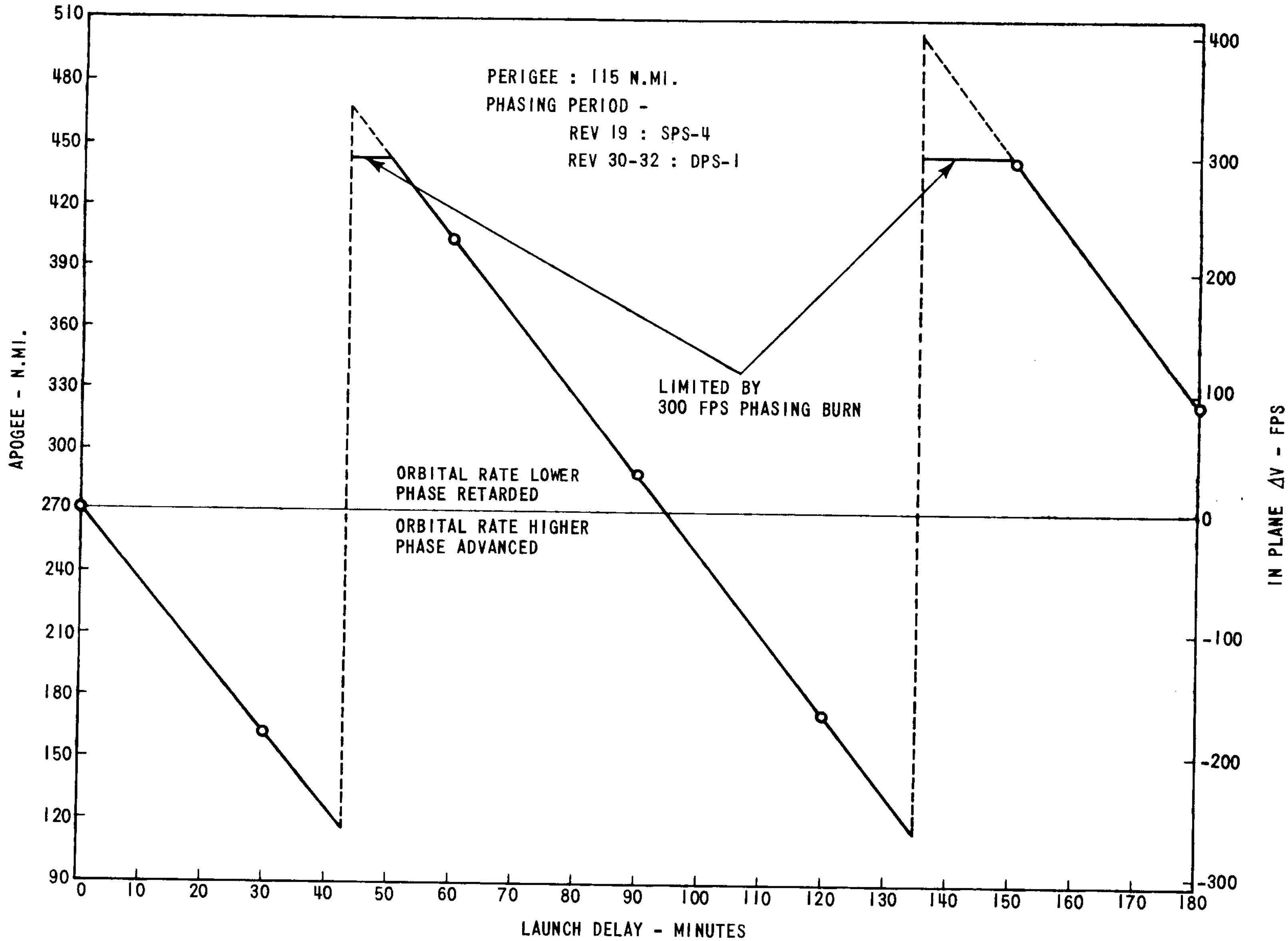
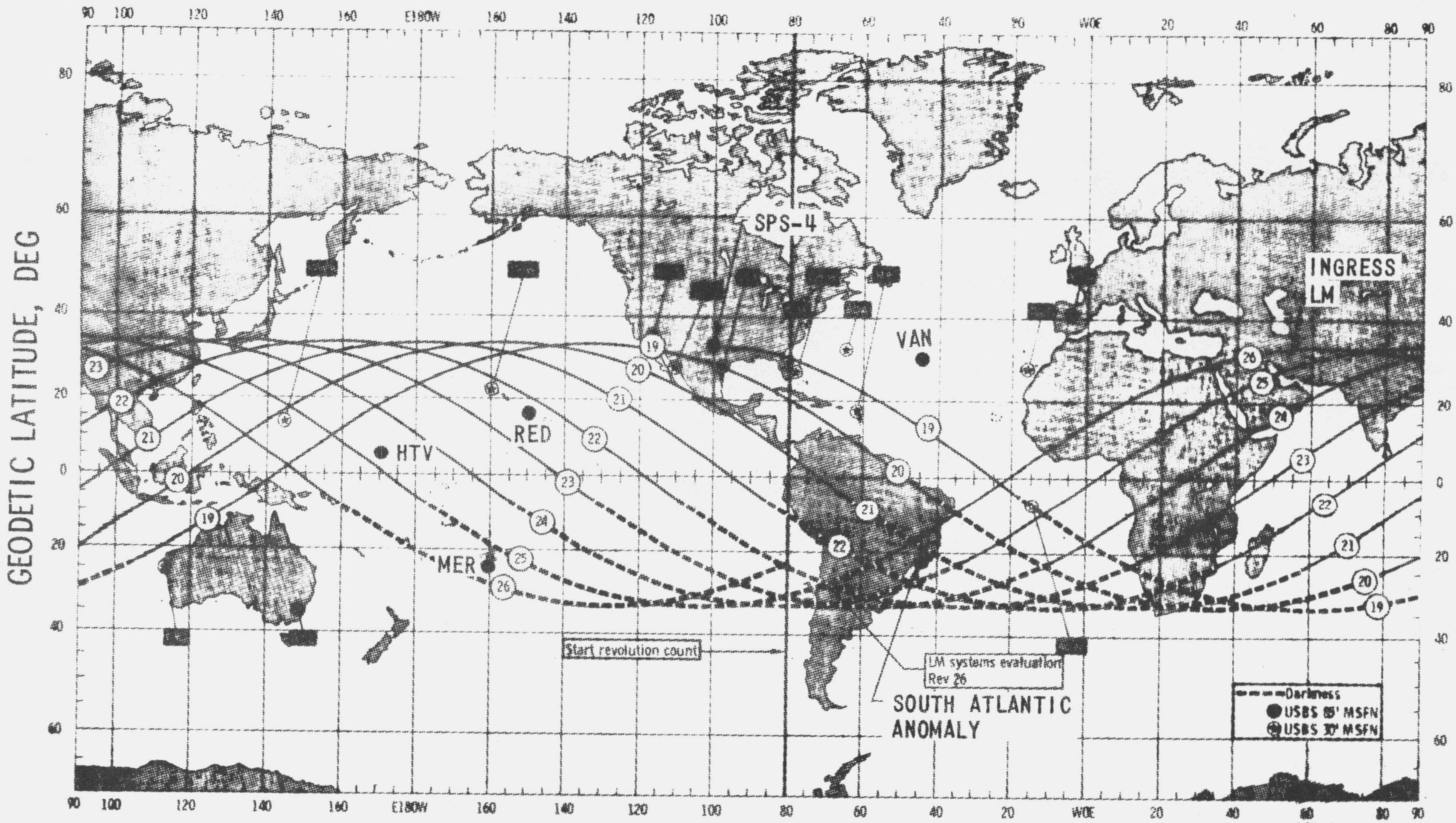


FIGURE 2 - APOLLO 9 REQUIRED ORBIT APOGEE FOR PHASING AFTER A LATE LAUNCH TO MAINTAIN PROPER LIGHTING/TRACKING FOR RENDEZVOUS

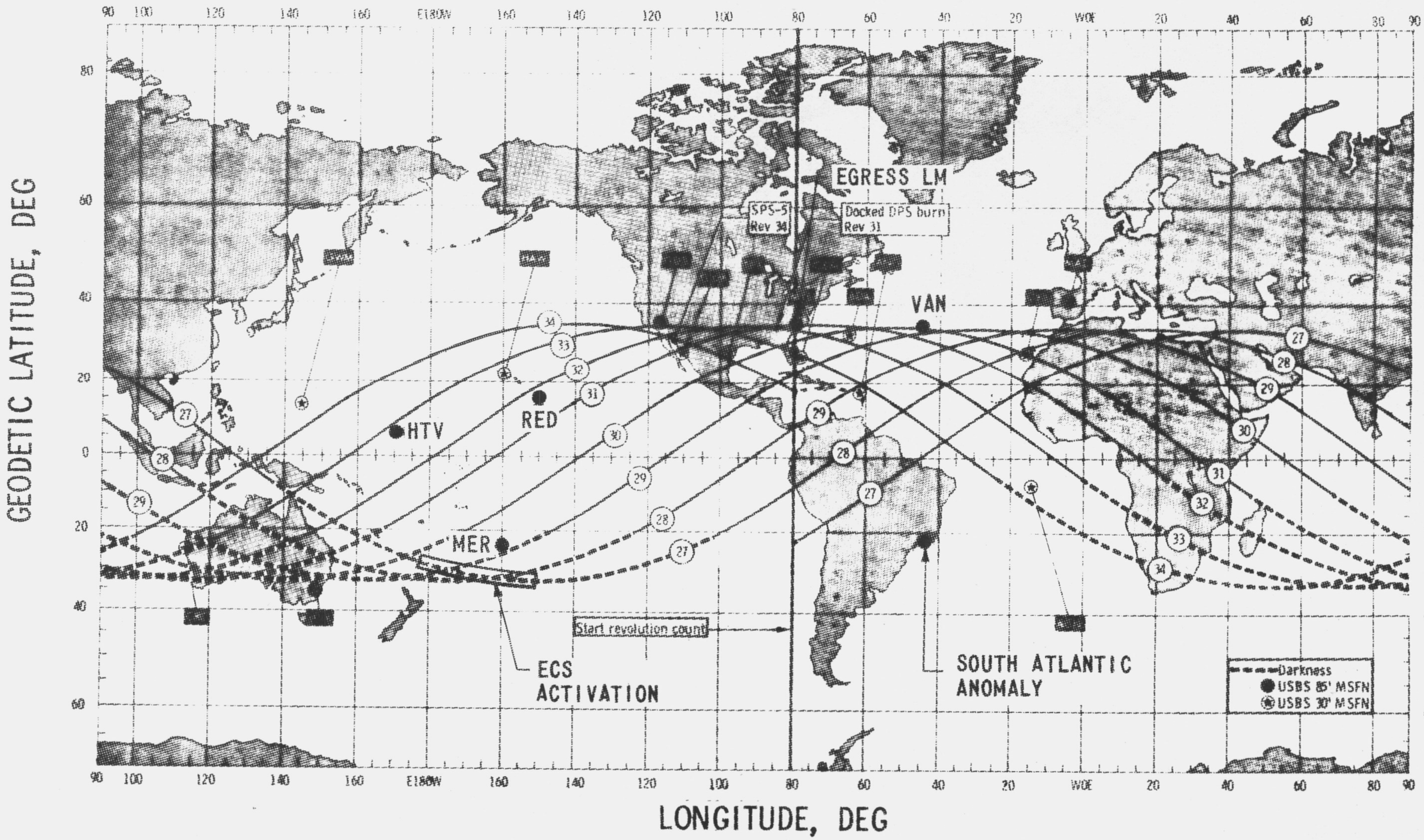


LONGITUDE, DEG

REVOLUTIONS 19 THROUGH 26.

VAN = VANGARD
MER = MERCURY
HTV = HUNTSVILLE
RED = REDSTONE

FIGURE 3 - APOLLO 9 GROUND TRACK



REVOLUTIONS 27 THROUGH 34.

FIGURE 3a - APOLLO 9 GROUND TRACK

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